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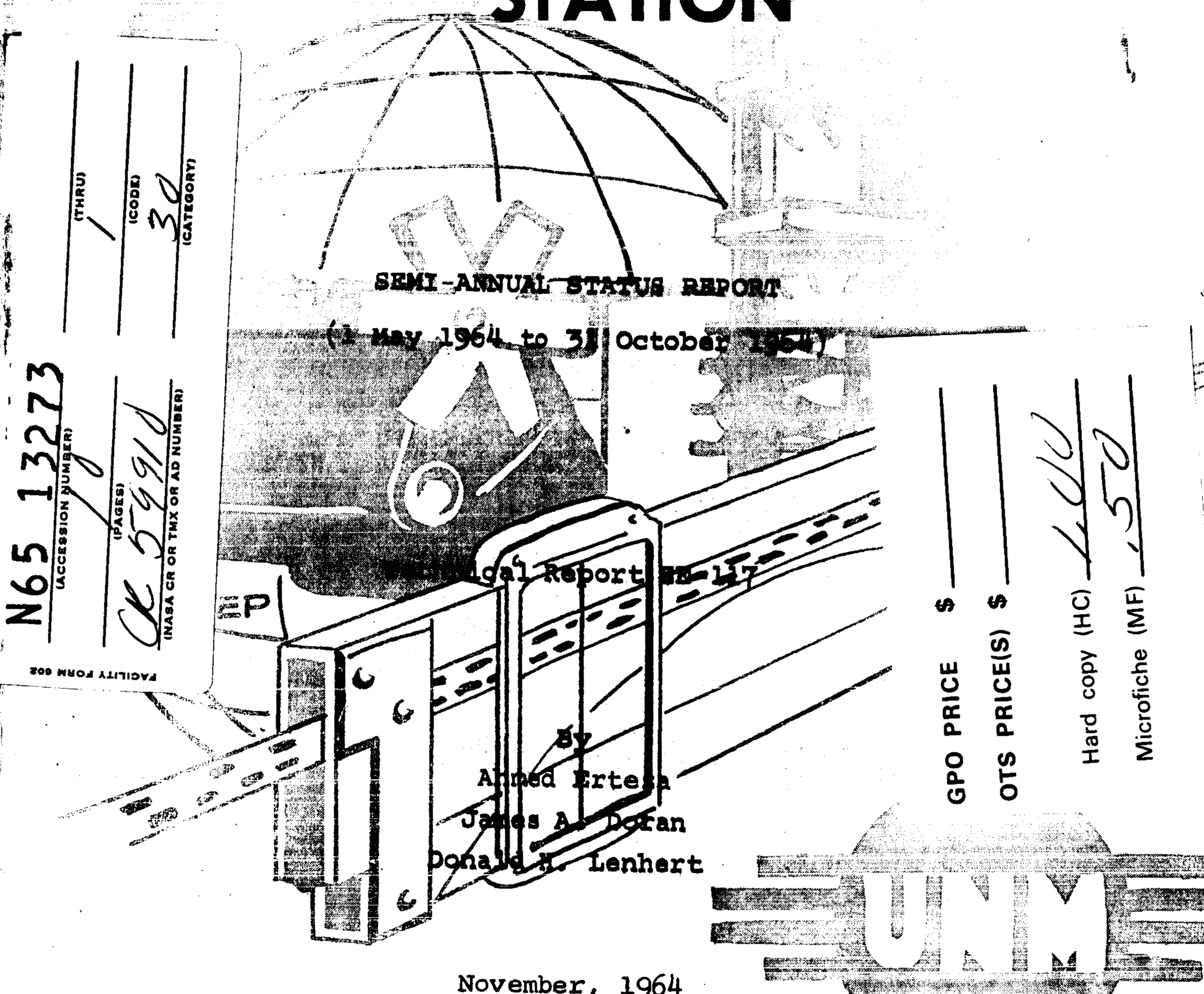

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(1 May 1964 to 31 October 1964)

Technical Report EE-117

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By

Ahmed Erteza
James A. Doran
Donald H. Lenhert

November, 1964

This work performed for
National Aeronautics and Space
Administration under Grant
Number NsG 129-61

The University of New Mexico
Engineering Experiment Station
Albuquerque, New Mexico

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ABSTRACT

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This report reviews work aimed at extending the concept of differential reflectivity to better determine the electromagnetic properties of the lunar surface. The two major areas of extension discussed are the transient solution of electromagnetic scattering and the effect of the relative velocity between the source and target on the scattered radiation. A short discussion is given in each of the areas of future investigation.

author

1.0 Introduction

This report summarizes the theoretical work which has been accomplished during the last six month period on NASA Grant 129-61. The purpose of these theoretical studies have been to extend the previously developed concept of differential reflectivity[1] in order to obtain better estimates of electromagnetic properties of scattering surfaces. The two major areas of theoretical study that have been pursued during this report period are: 1) the transient solution of scattered electromagnetic radiation, both monostatic and bistatic and 2) the Lorentz transform of the Hertzian potential. These topics are discussed in more detail in section 2.0.

2.0 Theoretical Studies

2.1 Transient Solution of Scattered Radiation

The purpose of this theoretical study was to determine the transient solution of beam-limited reflection from a smooth sphere (i.e. an idealized moon) using the concept of differential reflectivity. The approach used on this problem was to take the inverse fourier transform of the properly weighted steady state components of the reflected field. The weighting function was derived for a pulse of current in a short dipole.

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[1] Erteza, Ahmed, James A. Doran, Donald H. Lenhert, "The Concept of Differential Reflectivity as Applied to a Smooth Moon," Engineering Experiment Station, University of New Mexico, Technical Report EE-114, August, 1964.

During the investigation the question arose as to when to take the inverse fourier transform. There were three possible times: 1) After obtaining the differential reflected hertzian potential field ($\delta\vec{\Pi}_r$), 2) after the transformation of the differential reflected electric and magnetic field intensities ($\delta\vec{E}_r$, $\delta\vec{H}_r$), or 3) after integration of the differential reflected intensities over the illuminated surface. The proper place would be after $\delta\vec{\Pi}_r$ was obtained, however if terms of order $1/R^n$ are to be neglected for $n > 1$ then the inverse fourier transform can be taken after $\delta\vec{\Pi}_r$ has been transformed to $\delta\vec{E}_r$. Due to the propagating aspect of the wave the inverse fourier transform can not be taken after integration over the surface since terms giving the reflection during the interval of time between cessation of illumination of the nose of the sphere and the beginning of illumination of the edge of the beam at the surface will be lost. The only terms that appear during this time are DC and do not contain the transmitter frequency.

In the bistatic case for transient scattering some complication is introduced into the task of obtaining the scattered field at the observation point since that area of the scattering surface over which integration must be performed is itself a function of time. It is obvious that the area in question is that portion of the spherical surface bounded by the intersections of that surface with two confocal ellipsoids whose foci are situated at the source and observation points and the difference of whose semi-major axes is given by $\frac{\tau}{2c}$, where τ is the pulse length, in time, of the signal emitted by the source. The ellipsoid having the larger semi-major axis corresponds to the lending edge of the pulse and the one having the smaller semi-major axis to the trailing edge.

The intersections described above are rather involved functions of θ and φ, the polar and azimuthal angles, respectively, in a spherical coordinate system centered at the center of the sphere. In the solitary event that the source and observation points are on a line through the center of the sphere considerable simplification results since the intersections become circles dependent only on θ, if θ is the polar angle measured from the line joining the center of the sphere and the source. Evaluation of the integral is considerably simplified in this case. θ_1 and θ_2 which define the intersections are, of course, still functions of time. The complete results of this work will be reported at a later date in a separate report.

2.2 Lorentz Transformation of Hertzian Potential

In order to describe the reflected fields where there exists a relative velocity between transmitter-receiving antennas and the reflecting surface, an investigation was made to determine if there exists a Hertzian 4-vector. A Hertzian 4-vector was desired so that the dyadic Lorentz transform could be used to obtain the transformed incident field on the surface and then be operated upon by the dyadic differential reflectivity to obtain the reflected field. No such Hertzian 4-vector could be found. Therefore, to take into account the relative velocities mentioned above it will be necessary to either convert the $\vec{\Pi}$ vector to a potential 4-vector $\left[\vec{A}, \varphi\right]$, make the Lorentz transform, and then convert back to $\vec{\Pi}$ vector or to develop a new dyadic differential reflectivity for the potential 4-vector or the electric and magnetic field intensities. This work has been discontinued for the present, but will be pursued again at a later date.

3.0 Future Research

3.1 Electromagnetic Scattering from Deterministic Surfaces

An investigation of the scattered (reflected) E and H fields resulting from the interaction of a known source field with arbitrary deterministic surfaces will be pursued during the next six month period. Particular attention will be directed toward review of the concept of differential reflectivity with the object of developing application techniques which should extend the usefulness of this concept to the solutions of quite general electromagnetic scattering problems. The incident source fields will be assumed known and describable in terms of the fields of a discrete and/or continuous distribution of electric and magnetic dipoles. In addition, considerable emphasis will be placed on the relationship of the polarization of the scattered field to that of the incident field.

3.2 Electromagnetic Scattering from Statistical Surfaces

An investigation will be made of the reflection of beam-limited radiation from a sphere with statistical roughness (i.e. a rough moon) using the concept of differential reflectivity. The use of the concept of differential reflectivity will require probability distributions for both surface height and surface normal. These probability distributions are not independent and the relationship between them will be related to an assumed autocorrelation function for surface heights. Emphasis will be placed on polarization of the reflected wave and the depolarization by the surface. Use will be made of the transient solution in an attempt to determine the probability distribution of the received power at any instant of time in the reflected wave.

3.3 Acoustic Scattering from Surfaces

An investigation will be made of the acoustic scattering of a spherical wave from a surface using the concept of differential reflectivity. The purpose of this investigation will be to obtain a better justification for the use of the acoustic simulator to determine the electromagnetic scattering from a surface. At present the use of the acoustic simulator can only be justified on targets for which electromagnetic scattering has been experimentally measured. If the relationship of the longitudinal pressure wave reflected from a particular surface can be related to the direct polarized component of electromagnetic reflection, then theoretical methods of determining electromagnetic reflection can be verified by the use of the acoustic simulator and possible extended to cases which would otherwise require the use of large digital computers for numerical evaluation of certain integrals. Any results obtained taking into account body effect (i.e. transverse and longitudinal waves inside the target) will be of considerable importance in the study of the corresponding electromagnetic cases.

4.0 Publications

A portion of the time during this six month period was spent rewriting and condensing our paper entitled "The Concept of Differential Reflectivity as Applied to the Reflection of Beam-Limited Radiation by a Convex Body". This paper will be published in the February 1965 issue of "Radio Science, Journal of Research of NBS/USNC - URSI, Section D".

5.0 Travel

The following trip was made by research personnel for purposes of discussing research work, attending technical conferences and exchanging research notes with other people in this and allied fields:

Mr. D. H. Lenhert attended the Fall URSI meeting at the University of Illinois in October, 1964.